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CODING SYSTEMS AND THE COMPREHENSION OF INSTRUCTIONAL MATERIALS

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This study consists of three overlapping subprograms. The major subprogram focuses upon questions of how the organization of data in memory affects the acquisition of new information and the usefulness of stored information in response to various tasks. A second subprogram focuses upon the complementary issue of how different ways of encoding the information to be assimilated affects mastery and efficiency of processing. The third subprogram is aimed at bridging the gap between the classical work on memory which is based upon meaningless and simple stimulus materials and the current work on semantic memory.

0.0 TECHNICAL SUMMARY

The broad objectives of this contract deal with the structure of what an individual already knows about an area in relation to new material relevant to that area and in relation to tasks requiring the use of that material. How does the way that the material is originally learned (encoded) affect the ability to assimilate new information? How does the organization of stored information affect how well it can be used to cope with new tasks? How do task requirements and new information inputs, in turn, affect the organization of the pre-existing knowledge?

The objectives are pursued through a number of overlapping subprograms. Hyman and his associates have their subjects learn constructed textual materials. The materials consist of propositions about hypothetical individuals. Each individual is described in terms of properties or values on a number of attributes. One task to test how well subjects can retrieve and use the stored material is a matching task. The subject is presented with a pair of names and he has to decide if they are the same or different with respect to a designated attribute. The idea is to see if the subject can accomplish this match without being influenced by how many irrelevant properties the two names have in common. In two studies, Hyman found that most subjects show an influence of the irrelevant properties. They have an easier time in deciding two names are the same on the target attribute if the same two names are the same on other properties as well.

However, one subject did not show this interdependence of attributes. She apparently encoded the material differently from the other subjects. She organized it in terms of attributes rather than in terms of names. Hyman has

conducted a further study in which the form of initial encoding was deliberately manipulated. The hypothesis was that subjects who employed the attribute encoding would perform best on tasks such as the matching one in which they had to selectively retrieve and employ only part of the information about an individual. However, on other tasks that required retrieving and combining all the information about an individual, the name encoding strategy would show up better.

Hyman and his associates are planning some changes in the task they employ to see how effectively their subjects can use the stored information. In particular, they will switch to a verification latency procedure in which they can simultaneously probe how well a subject can selectively retrieve as well as integratively retrieve information from the same content area. The overall goal is to discover which ways of initially mastering and encoding new subject matter will lead to more effective performance in various tasks requiring the use of that subject matter.

Reicher and his associates have begun a series of experiments on the use of symbolic codes which stand for large chunks of information. They are looking at the differences between codes learned by rules as opposed to those learned by rote. They have also begun a set of experiments on the problem of segmentation--how input is broken up by the recipient into component parts.

Begg and Wickelgren finished a study on recognition memory for sentences. The results indicate that the forms of the retention function for entire sentences is the same as the form for other types of verbal memory such as word pairs, words, etc. To the extent that this finding is general it suggests that what we have learned about memory for nonsense syllables and isolated words may have some applicability to more complex and meaningful materials.

Keele finished one study and began another on the important question of how we learn the pattern in sequential materials. Schaeffer did not return from his sabbatical until the end of the present reporting period. But he has initiated projects on the rehearsal process and on schema formation.

At the end of this period we finally began our move into new quarters at Straub Hall. The move resulted in a disruption of our work, but when it is completed it will greatly enhance our capabilities to do many experiments at once. We also had some unanticipated problems with our PDP-15 which delayed some of our experiments during this period. On the other hand, we decided upon and ordered a new computer system to supplement the two computers we now have at the core of our automated laboratory.

1.0. INTRODUCTION

This report summarizes the work of the first six months done under the contract entitled "Coding Systems and the Comprehension of Instructional Materials." This period was essentially a "tooling-up" phase; it consisted of pilot work and feasibility studies. Because of unexpected problems with our PDP-15 and our move to new quarters in Straub Hall (see further comments later in the introduction) we encountered some frustrating delays. One of our investigators, Benson Schaeffer, did not join us until the end of this period. Consequently, we have little to report in the form of "conclusions." Despite the preliminary nature of our data and the unexpected delays, the work has been quite encouraging. We have found that many of the manipulations and experimental techniques that our projected plans depend upon can be implemented. And the preliminary findings seem quite promising.

1.1. Objectives

In our application to obtain support for our project we wrote:

> "The proposal consists of three overlapping subprograms. The major subprogram focusses upon questions of how the organization of data in memory affects the acquisition of new information and the usefulness of stored information in response to various tasks. A second subprogram focusses upon the complementary issue of how different ways of encoding the information to be assimilated affects mastery and efficiency of processing. The third subprogram is aimed at bridging the gap between the classical work on memory which is based upon meaningless and simple stimulus materials and the current work on semantic memory."

The emphasis upon "coding systems" indicates our intention to apply the techniques and findings from our previous ARPA-supported project on "Coding Systems in Perception and Cognition." That project provided us with a detailed model of how individuals select, integrate, transform and otherwise process information in performing a variety of tasks requiring speed, accuracy and skill. The project also supplied us with a variety of tools for operationally studying such information processing in detail--the probe technique, chronometric analysis, etc. In addition, we developed both the hardware and software necessary for automating the control of many phases of the experimental procedure. These"products" will help us considerably to study the comprehension of instructional materials from an information processing viewpoint.

The earlier project employed stimulus materials such as dot patterns, letters of the alphabet, nonsense syllables and the like that were deliberately free of everyday meaning and associations. The materials were also relatively simple in that they consisted of small samples from populations that were

themselves well defined and limited. Furthermore, the tasks required only one or two sessions of the subjects' time and did not extend over intervals of more than a few days or a week or so at the most.

The present project moves closer to "reality" in that it will emphasize stimulus materials that are semantically meaningful, highly organized, of considerable length and of a structural complexity comparable to that of instructional materials. Such material requires much longer periods and more naturalistic methods of mastery on the part of subjects. We intend to study our subjects over periods of several weeks and longer.

We think that our automated laboratory as well as what we have learned from the previous project has prepared us for moving on to the study of performance within this more realistic context of mastery. In addition, recent developments in linguistics, psycholinguistics and computational linguistics have also supplied us with conceptual and technical tools that promise to give us a way to specify stimulus dimensions and structures in complex material that was previously lacking. One way that we have profited from these developments is in the construction of realistic textual materials in terms of basic underlying propositions as the unit. We believe that we will soon be able to reconstruct or adapt actual instructional materials and short courses in such a way that we can specify the structural nature and complexity of the material at each point in the sequence.

1.2. The General Approach

We are experimental psychologists. Our basic tool is the controlled, laboratory experiment. In addition, we work in the tradition of what is variously called "the human information processing approach" or "the human performance approach." This approach implies a theoretical orientation, a

set of paradigms, and a set of experimental techniques. The books by Lindsay and Norman (1972), Keele (1973) and Posner (1974) give a general feeling for this approach.

Within this framework, as I indicated in the discussion of our objectives, we hope to tackle the problem of instructional materials by employing stimulus materials that closely simulate, or actually are, instructional materials in their complexity and meaningfulness. We also intend to use amounts of material to be mastered and time intervals over which the mastery is studied that more closely approximates actual learning situations. At the same time, however, we hope to retain the controls and generality that come from well-controlled laboratory experiments that are designed to answer questions within the context of more-or-less elaborated formal models.

1.3. The Subprograms

Hyman and his associates have been exploring the possibility of having subjects learn constructed textual materials. The idea is to partially control the content and organization of the subject's semantic memory with respect to a restricted area of knowledge. Once such a semantic network is "loaded" into the subject's memory, then various implications of this particular organization of the material can be investigated. Reicher has been investigating the role that symbols or codes that stand for larger complexes of information have in information processing. He has also begun to study the problem of segmentation in comprehending linguistic materials. Wickelgren and his associates have been investigating the extent to which the same dynamic laws of memory hold for the traditional areas of rote memory and the newer focus of semantic memory. And Keele, who worked on our project this past summer, focussed upon the problem first made famous by Lashley--that of

the patterning of sequential behavior.

Each of these subprograms will be described in a little more detail in later sections of this report.

1.4. New Equipment

After carefully reviewing the new developments on the computer market, we finally decided upon an alternative to expand the capability of our current automated laboratory system which is based upon a PDP-9 and a PDP-15 computer. When we submitted the proposal for this contract, our intention was to expand our capability by adding a new station to our PDP-15. We have subsequently changed our minds. One reason was that, as a result of a National Science Foundation grant to facilitate our undergraduate teaching, we have added two new stations to the PDP-15. Although the PDP-15 could still probably handl another station, we have some apprehension about placing such a heavy reliance upon this single piece of equipment. When the PDP-15 is shut down for maintenance work or for repairs, the number of experiments that are simultaneously brought to a standstill is that much greater.

A second reason is the coming on the market of small, inexpensive computers such as the PDP-11 and the Nova 2/4. Upon careful investigation, these small computers seem to provide us with both the possibility of developing an independent system and to achieve our original objectives plus additional benefits. We spent three months carefully pricing and evaluating the costs and benefits of three possible systems based upon the PDP-11, three possible systems based upon the Nova 2/4, and our original plan to add a terminal to the existing PDP-15. We rejected some other systems because they were far beyond the costs allotted in our present budget.

We eliminated the various systems built around the PDP-11 because the total cost to make them compatible with our present system turned out to be prohibitive. And even then those systems within our price range had insufficient memory to enable us to use Fortran or some other simple programming language. We would have been restricted to machine language and this would severely cut down on the number of staff and assistants who could use the facility.

The Nova 2/4 met our cost limitations and gave us double the memory that we could get from the other systems. Although it requires us to deal with new companies, we can rely upon the experience of one of our former students who has worked with two Novas during the past year. He assures us that the machines are reliable and will more than meet our requirements. Furthermore he has developed software that he can supply us, which will make the new system operable for us almost upon arrival.

The new computer, the Nova 2/4, is manufactured by Data General. The reason we can get so much memory relatively cheaply is that the memory operates more slowly than in our present computers. For our uses, however, this slower speed will not be a limitation (our speed of operation is much more limited by the external devices driven by the computer). The configuration we have planned will allow the Nova and our existing PDP-15 to correspond via magnetic tape. The Nova is very small and would allow us some portability.

We have ordered the Nova and the associated components, after receiving permission from the appropriate agencies for this change, at a total cost that does not increase our total budget. We hope to have delivery by March of 1974 and be ready to operate with it soon afterwards. This facility should greatly increase the productivity on this project beginning in the second year.

1.5. Move to Straub Hall

Renovation of the basement of Straub Hall was finally completed at the end of this reporting period. By the end of the year, the automated laboratory should be completely moved to the new laboraties in Straub and be ready to operate again. The new laboratory gives us considerably more room, better sound insulation, and will enable us to run many more experiments simultaneously with our small computers. The dismantling of the computers and related systems, in preparation for the move, as well as the installing and connecting of cables in the new laboratory has resulted in temporary disruption of the experiments during the latter part of this reporting period and during the early part of the next reporting period. We are using this "downtime" to analyze data and to make plans for the next experiments.

1.6. Attention and Performance V.

Both Hyman and Keele read invited papers at the Fifth Conference on Attention and Performance at Saltzjöbaden, Sweden in July. Both papers dealt with work partially supported by the present project. Hyman and Frost's paper on "Gradients and Schema in Pattern Recognition" summarized a series of studies which had been initiated under the previous ARPA contract, but whose final analyses and preparation for publication were supported by the present contract. Keele's paper on "Representations of Motor Programs" discussed research he had done this summer explicitly for the present project.

The conference gave Hyman the opportunity to interact with many of the psychologists most active in memory and semantic memory. Especially of value was a special discussion on the current situation in memory research involving such individuals as Broadbent, Morton, Triesman, Baddely, von Wright, Atkinson, Schiffrin, Norman, Mander, La Berge, and others. Interestingly

enough, in line with the current theoretical work of Wickelgren on our project, the consensus among these memory experts is that the distinction between short-term and long-term memory may no longer be viable in terms of the latest findings. Of more relevance to the present program, was to be able to discuss with the various investigators what they are currently doing in the areas of semantic memory that most overlap with the present project.

1.7. Seminar on Semantic Memory

During the Fall Quarter, Wickelgren, Hintzman and Hyman jointly conducted a graduate seminar on semantic memory. The seminar carefully went through the recent book by Anderson and Bower on Human Associative Memory (1973). The book presents a model of semantic memory which is closely related to the ideas of semantic networks and structures that motivated the present research project. The present proposal was based on Frijda's (1972) idea of an information molecule as the basic unit of a network. This information molecule, consisting of two informational atoms connected by a specified relation, closely resembles the proposition that Anderson and Bower take as the basic unit of their memory system.

The students in the seminar were required to generate a research proposal based on the key issues emerging from the seminar. Some of the proposals were so excellent and so relevant to the heart of this project, that we have decided to support two, and possibly three, of the student projects during the next reporting period.

1.8. Overview and Prognosis

The first six-month period was devoted to examining the feasibility of certain paradigms for carrying out our objectives. We feel fortunate in

that, for the most part, the new paradigms that we tried out seem to promise us a way of dealing with the complexities of semantic memory. Our misfortunes came from unanticipated and anticipated delays in our experiments as a result of our moving to Straub Hall and as a result of what we hope are temporary malfunctions in our PDP-15 system. The most recent experiment of Hyman and his associates, for example, was possibly marred because of unpredictable breakdowns in the middle of experimental sessions. We may have to repeat that experiment. Despite these setbacks, however, we are farther ahead of our projected schedule for this time than we originally had expected. This progress has been due to the fact that some of our new paradigms have worked much better than we had anticipated.

The next period should be more productive, especially after we get settled into our new laboratory quarters. We are not sure how much time will be lost in getting used to operating in our new surroundings and making our automated laboratory functional again. In the long run, however, we expect our productivity to increase by an order of magnitude. This should begin to show during the second and third years of the current project.

2.0. Hyman and Associates

The subproject of Hyman and his associates focusses upon the role of the organization of semantic memory with respect to a given subject matter. One preliminary problem is to diagnose and describe the organization of such a memory. Attempts to theorize about and describe naturally existing semantic memories with respect to specified domains have been made by Collins and Quillian (1969, 1972), Conrad (1972a), Deese (1965), Fillenbaum and Rapoport (1971), Miller (1967, 1969), Schaeffer and Wallace (1969, 1970), among others.

Once the content and structure have been specified, then several questions can be investigated. How do different ways of organizing the same content area in semantic memory affect the effectiveness of using that stored information in varying contexts and for various task demands? Are some organizations better adapted for some tasks while others are more appropriate for others? A related question is how the organization of the current information affects the assimilation and comprehension of new information to the same area.

The preceding questions use the organization of semantic memory as the independent variable. They focus on how existing semantic structure a affects the assimilation of new information, the retrieval of old information, or the ability to use stored information in new situations. Another set of questions makes the organization of semantic memory the dependent variable. They focus on the reciprocal questions of how the organization of existing semantic memory is affected or altered to accomodate new, possibly contradictory, inputs or in response to new task requirements.

Then there are questions about individual differences in organization of semantic information about a given domain. Do experts within a given content area simply possess more information? Or do they have the information organized in a more efficient manner? Can we improve performance of others by teaching them to reorganize their information in a way that better matches that of the expert?

These are the general questions that provide the theme for Hyman's program of research. The stumbling block of prior attempts to deal with similar questions, in our opinion, has been the theoretical and practical difficulties of specifying and describing the semantic structure of a given

area for a specific individual. The existing techniques of word association, multidimensional scaling, clustering, confusion measures have to make very strong a priori assumptions or involve the subject in such difficult and time-consuming judgments that they probably alter his existing structure and, worse, may even impose a structure upon the content.

Efforts so far have suggested a variety of different structures which may depend upon the particular subject matter area, the subjects used, the task required of the subject to make his structure explicit, the assumptions made in analyzing the judgments, and particular algorithm employed to make the analysis. We do not think that this variety of structures is entirely artifactual. We think most of the types of structures that have been isolated or postulated have a range of situations and contexts in which they validly describe important aspects of semantic memory.

Our approach to this problem of describing semantic structure has been to circumvent it. We do not try to assess what the structure is for an area of knowledge that the subject already brings with him to the laboratory. Instead, we create a new content area and load both a content area and a known structure into the subject's memory. To the extent that we can successfully load both the content and its organization into a subject's memory, we can more precisely determine how different organizations of the same content function.

Consequently, the emphasis of our subprogram during this initial phase of the contract was to evaluate the feasibility of loading such semantic structures into subjects' memories. We believe that this phase of the project has so far proven to be both tractable and feasible. Some of the consequences will be mentioned below.

2.1. Hyman and Frost on Pattern Recognition

As mentioned in the Introduction, Hyman and Frost presented their paper "Gradients and Schema in Pattern Recognition" to the Fifth Conference on Attention and Performance in Sweden during July. A prepublication version of this paper accompanies this report. The paper summarizes a series of studies on pattern recognition that were begun during the earlier ARPA contract. The final data analyses and preparation of the paper were supported by the current contract.

The work on pattern recognition involved learning to classify dot patterns into appropriate categories. As such, it does not directly deal with semantic memory or instructional technology. Yet the work is highly relevant for a number of reasons. One compelling reason is that models of pattern recognition appear to be formally closer to models of comprehension than do other models of cognitive processes such as those employed to deal with human problem solving and decision making. From the outset, models of pattern recognition have involved networks with nodes and connecting lines indicating relationships. Also, these models have more often focussed on branching, parallel processes rather than sequential, stepwise processes. Semantic network models, in all these respects, have a very close affinity to pattern recognition models.

An important issue in the study of pattern recognition is how to include within the same framework processes that involve distance concepts measured in a continuous medium with processes that involve discrete categorization of items into mutually exclusive and possibly discontinuous classes. A related question involves the distinction among template, feature, and distance models.

All these distinctions find parallels in attempts to deal with semantic networks and operations upon them.

Hyman and Frost compared three models of pattern recognition. An exemplar model assumes that the subject stores representations of each instance of a concept that he encounters. When he encounters a new object he compares it with the internal representations he has stored for various concepts. If the object is sufficiently similar to one or more stored representations of a given concept, he "recognizes" it as an instance of that concept. As our own work demonstrates, this model has a range of situations over which it is valid. Its main weakness for serving as a general model of how to recognize and classify new patterns or words or objects is the tremendous load it places upon memory and memory search processes.

Since Bartlett's (1932) classic work on memory, various versions of a schema model have been proposed to explain how individuals can deal with new patterns and information in an efficient manner (Attneave, 1957; Posner & Keele, 1968). The schema model assumes that the subject creates a single, composite representation to replace the individual representations of the separate exemplars for each category. When the subject encounters a new object he need only compare it with the single stored schema for each concept to decide which, if any, of his stored concepts the new item belongs to. Posner and Keele, for their situations, found evidence to support this model. Their results have been confirmed by others. Hyman and Frost found that this model indeed best describes the classification behavior of subjects for at least one type of pattern.

This schema model, borrowed directly from research on pattern recognition, has become quite popular in recent studies of semantic memory.

Hyman and Frost's third model was the Rule Model. This model assumes that the subject abstracts from the exemplars of the different classes those common dimensions or attributes on which the members of the different classes can be discriminated. This assumes, of course, that subjects can find such dimensions which can be used to discriminate members of one category from another. Again, Hyman and Frost found that this model, too, had its range of validity. The three different models are by no means mutually exclusive nor exhaustive: The lesson these findings hold for pattern recognition probably hold, if anything more so, for semantic memory. The issue will be not to find which model of classification and comprehension best fits all situations, but under which conditions can we expect to find one model operating as opposed to the others?

2.2. Hyman, Polf, Wedell. Experiment I.

The first experiment in our series served a number of objectives. We wanted to see how feasible it was to "load" a constructed data base into a subject's memory and then test the consequences. The data base consisted of simple propositions, embedded in a quasi-narrative, about hypothetical individuals. Each individual was characterized by at least three propositions. One proposition told where in the hypothetical city of Plainview he lived. Another told which subculture he belonged to. And the third informed the reader whether he was for or against the construc of a proposed civic center.

The attribute of geography had four locations (NE, NW, SE, SW); the attribute of subculture had four values (college, business, retired, military);

and the attribute of issue had two values (for, against). This created the possibility of 4x4x2-32 combinations or "roles" into which we could assign individuals. We deliberately created "structure" or redundancy in our data base, however, by deliberately using only 16 of the possible 32 roles. We did this by creating a dependence between subculture and issue. All members of the college and business subcultures were for the civic center and all members of the retired and military subcultures were against the civic center. This reduced from 8 to 4 the number of combinations of values on the attributes of subculture and issue. We kept the attribute of geography orthogonal or independent of the other two attributes--all 16 combinations of the four geographical locations with the combined four subculture-issue combinations occurred.

With this built-in structure we hopefully created a situation in which each item or individual in our data base would be stored as a member of two independent structures. One structure was the geographical quadrant of the city. The other was the hierarchical structure created by issue and subculture (the subcultures being "nested" within the values on issue). We hoped this might provide a start towards studying the issue of multiple versus single memory locations for the same item. Koler's research on bilingual subjects (1968) provides an example of the issue we were interested in. He found evidence that some words, regardless of whether they occurred in French or English, seemed to activate or retrieve meanings from a single, common memory. Other words, however, apparently retrieved meaning only from a separate memory for English or for French.

Another purpose was to see to what extent the subject could retrieve information about an individual's value on a designated attribute without

having to retrieve or "lookup" the information about the individual's values on the other two attributes. This issue of whether selective retrieval of information is preceded by a prior stage in which all the meanings of a word are activated was examined by Carol Conrad in work supported by our preceding contract (1972b). Conrad concluded that even when the preceding context was clearly unambiguous as to which meaning of an ambiguous word was intended, the other meaning of the word was also activated by its occurrence. For example, in the sentence "The sailors sailed into the port", the alternative for "port" meaning "wine" was shown to have been activated prior to a selection stage in which the intended meaning of harbor was determined by the context. This finding lead Conrad to conclude that even when the context is unambiguous, there exists an automatic lookup stage during which all the meanings of a word are activated.

Procedure. The data base was created to include 16 of the possible 32 "roles" as described above. We assigned 28 hypothetical individuals to the 16 roles. Six of the roles were represented by one individual, eight by two individuals, and two by three individuals. Two things were done to add realism to the data base. The names employed were drawn from the local telephone directory and a narrative was written around the 28 names in which additional details were added. Some individuals, for example, in addition to being identified by occupation, geography and issue were described as meeting together for a weekly poker game. Two individuals were engaged to be married. Some of the individuals were active in the campaign to influence the vote on the civic center. Undoubtedly, these additional

embellishments made some individuals more salient than others; they also created stronger ties between some individuals than between others.

Three of the experimenters served as subjects in a preliminary version of the experiment. Four paid subjects provided the main body of data. Each subject was instructed to study the narrative and learn as much as he could about the individuals in the narrative before coming to the first testing session. The subjects were tested on their mastery by a written examination in which they were given the 28 names and had to supply the appropriate value on each of the three attributes for each name. If the subject could not accomplish this on the first test, he was sent away with instructions not to return until he had mastered the material. Only one of our four subjects seemed to have difficulty in mastering the material. This apparently was a motivational problem, because he achieved a perfect score the next day after being informed that we would have to eliminate him from the experiment. After mastering the material in the data base, each subject then appeared in 5 different experimental sessions.

During the first session, pairs of names appeared on the cathode ray scope, and the subject had to respond by pushing a right hand key if the two names were the "same" on their geographical value; otherwise he pushed the "different" key. During the second day, the subject had to decide whether the two names were "same" or "different" on their value of issue. The third session was again devoted to issue and the fourth was on geography. For completeness, we ran a fifth session in which the target attribute was subculture. Only one attribute was relevant during any one session. The sessions lasted approximately an hour each.

Because we wanted to achieve enough replications of each pair of names to obtain stable data for each subject, we used only 48 pairs of names out of the total set of 378 possible pairings.

Results. The dependent variable was reaction time for recognizing a given pair as "same" or "different" on the relevant attribute. Our independent variable was the number of shared properties the two names had on the irrelevant attributes. When the target attribute was geography, the number of shared properties on the irrelevant attributes of occupation and issue made a consistent difference both on the "same" and the "different" matches. When two names were the same on occupation and issue as well as geography, the time to react "same" was 1.34 seconds. But when the two names differed on both occupation and issue, the time to respond that they were same on geography rose to 1.83 seconds. When the two names differed on both issue and occupation as well as geography, the time to react "different" was 1.94 seconds. But when the two names were the same on occupation and issue, the time to respond that they differed on geography rose to 2.41 seconds. These findings when geography was the relevant dimension are consistent with the idea that the subject automatically retrieves all the information about each name in making his judgment about a single attribute.

The results when issue was the relevant attribute present a different story. When two names differed on both geography and occupation, the time to recognize them the same on issue was only .06 seconds slower than when they were the same on all attributes. Because of the interdependence of issue and subculture, two names that differ on issue had to always be different on subculture. However, reaction time to recognize a pair as

different on issue was only .08 seconds when they were the same on geography. These results when the target attribute is issue suggest very little affect of the irrelevant dimensions.

Discussion. These findings are susceptible to alternative interpretations. Issue was a dichotomous attribute; whereas geography had four values. It could very well be that the presentation of a name starts an automatic lookup process that retrieves the values on each of the attributes in parallel. But it may take longer to retrieve the value for a 4-valued attribute than for a 2-valued attribute. This differential could explain the assymetry of our findings. Another possibility is that the subjects organized the names in their memory primarily in terms of the dichotomous attribute of issue. When given a name they first retrieve the value for issue. If the task demands only this information, the search can stop at this point. If the task demands information about geography, however, they have to get to geography by first retrieving the value on issue.

In addition to ambiguous interpretations of our results, our initial study suffers from a variety of other confoundings. We used only 48 pairings of the 378 possibilities. With many repetitions over several sessions of the same 48 pairs, it is possible that subjects could have learned specific information about these particular pairs. For example, some pairs were always "same" no matter what the target attribute. The fact that some names were related by textual relationships extraneous to the three attributes employed in our testing also created systematic, but unwanted variations in response times. For example, the pair of individuals who happened to be engaged in the narrative, were responded to as "same" much faster than other pairs that shared all three properties in common.

By employing a variety of supplementary analyses we convinced ourselves that the results could not be explained away by many of the obvious artifacts that might have arisen because of the various confoundings. Nevertheless, we felt we had tried to accomplish too many goals with one study. The next study was undertaken, consequently, to reduce the number of variables and to unconfound some of the possible findings.

Overall, however, this first study was quite encouraging. It convinced us that we could successfully load a narrative-like data base into subjects' memories and, despite great individual differences in strategies employed to master this material, we could obtain highly systematic and meaningful data in later tests based upon this implanted data base.

2.3. Hyman, Polf, Wedell. Experiment II

In this second experiment we made a number of changes to unconfound and control more sources of variation than in the preceding study. We used four attributes to describe our individuals, but this time all attributes were dichotomous. We also eliminated the redundancy that we used to create structure in the preceding experiment. This time all the attributes were orthogonal in the sense that every one of the $2^4=16$ possible roles was represented. Rather than allow the saliency of the individuals be a haphazard affair, we attempted to deliberately manipulate the saliency of individuals. Within each role we had two names; for one name in each role we deliberately added more descriptive information. This was an attempt to make one name salient and one less salient in each role category. As before, the basic propositions for each name were embedded in a quasi-narrative about the hypothetical town of Dijon through which a river flows.

Each individual was characterized by which bank of the river he lived on (East or West); whether he worked as a Planter or Plasterer; whether his recreational hobby was Jogging or Shuffleboard; and what type of bridge he wanted to see built across the river (Wood or Stone). An attempt was made to use realistic, but not peculiar names. And no explicit connection between individuals was included as part of the narrative. We included a total of 36 names, four names were added to the 32 names that resulted from having one salient and one non-salient name in each of the 16 roles. The four names were added in order to create some pairs of names that were from the same role category and that were both salient or both nonsalient.

Procedure. Four paid subjects first mastered the narrative and then participated in 8 testing sessions plus an additional session two weeks after the final session. Each subject was allowed to study the material any way he wished and then came in for an assessment of how well he knew the material. The assessment session presented the subject with two of the three components of a basic proposition and he had to fill in the third component. For example, he was given a name, geography and he had to respond with East or West for that probe. It took several sessions for subjects to master this material.

After reaching criterion, the subjects were tested in sessions similar to those of the preceding experiment. Each attribute served as the relevant dimension for comparing the name pairs in two different sessions. The total of eight testing sessions, counterbalanced, were administered in a different order for each subject. After an interval of two weeks the subjects

were brought back for one additional session to see how fast they retrieved the value of a given name on a specified attribute.

Results. The subjects employed rather elaborate and idiosyncratic strategies for encoding the data structure. Because of the repeated testing necessary before they demonstrated sufficient mastery of the material, each subject quickly realized that all the textual material other than the names and corresponding values on the four attributes was extraneous. Consequently, each subject developed a strategy based only upon these basic propositions. As expected from this strategy, the "salience" of the name as manipulated by us had very meager effects. There was a significant, but very small, effect of the saliency of name pairs during the early testing trials. By the time a subject had participated in half of the sessions, however, every trace of the saliency had dropped out of the response latencies.

Although the encoding strategies described by each subject were elaborate and highly idiosyncratic, they could be divided into two very broad classes. The strategies of 3 subjects involved coding all the attribute-values for a given individual together with the name. The fourth subject, however, learned the attribute values for each name separately for each attribute. She first learned the 18 names that lived on the East bank in alphabetical order. She did not try to learn the list for those on West bank, correctly assuming she could get at these through elimination. After mastering geography in this way, she then learned the 16 names, realphabetized, that belonged to the Planters on the work attribute. Again, she then could identify the remaining 16 by default. She did the same for the remaining two attributes. As we will see, this

division of the encoding strategies corresponds to differences in the subjects' abilities to function efficiently in our testing task.

The data for three subjects showed an effect of the irrelevant attributes on time to recognize two names as "same" on the relevant attribute. Unlike the situation in the preceding experiment, however, the time to recognize two names as "different" was not influenced by the number of common properties on the irrelevant dimensions. Dr. Harold Hawkins, who is a visiting professor in our department this year, suggested one model that might account for this assymetry between same and different classifications. Essentially, he suggested that the subject sets up in memory a positive target set of names when he is given the task of matching names on a given attribute. If the relevant attribute is geography, say, then the subject would set up a positive set consisting of those names that, say, live on the East bank. When presented with a pair of names, the subject would search serially through his positive set to find a match. If one name appeared on his list he would continue on through the list until he found the other name. If he found it he would respond "same". If he found only one name on the list, he would respond "different." If he found neither name on the list, he would respond "different." Such a model would easily account for the fact that essentially the different response has the same reaction time for all pairs. And it would account for the effect of irrelevant dimensions on "same" if the names on the positive list were arranged in terms of their similarity on the irrelevant dimensions.

Various other implications of Hawkins' model, however, did not hold up. For example, if the model is correct, the dependence of the "same"

response or common irrelevant properties should hold only for one category of the relevant attribute and not for the other. But in our data, the dependence tends to show up for both categories.

Adam Reed, a graduate student, has suggested another search model that is better in accord with the data. He suggested that the subject has set up in his memory a single list of the 36 names. Regardless of which dimension is relevant, he searches through this list serially, in the same order. Say the task is to decide if Norman Osbourne and Arthur Backman work at the same occupation. The subject's search strategy is to scan the list for a perfect match to his probe. His first probe consists of "Norman Osbourne works as ______", and "Arthur Backman works as ____." He scans the list until he comes to a proposition whose first two terms match either of these probes. Say he first comes upon "Norman Osbourne works as a Planter." He now inserts "Planter" in his probe for Arthur Backman. He continues through his list until he finds a match to "Arthur Backman works as a Planter." If he does he stops and responds "same." If he does not find an exact match he continues through the entire list and then responds "different." Such a model easily accounts for why all the "different" responses are generally slower than the sames and do not vary as a function of irrelevant properties. If the names on the list are arranged according to similarity between adjacent pairs on shared properties, the model would also account for a tendency of "same" responses to be faster for those pairs that share common properties. Because it is impossible on a linear arrangement of names to be consistent in keeping names with shared properties together, there are further implications of

the model. With some additional plausible assumptions, the model predicts that the effect of the irrelevant properties on the "same" responses will be very strong for one attribute and progressively weaker for the others. Our first check on this seems to suggest that this is so.

We have still not done all the analyses to see if this latest model or some other model can account for all our data. Finding an appropriate model to account for these data, of course, if of considerable interest. But our major concern is with another implication in the data. As indicated, only three of the four subjects showed this tendency for the "same" responses to depend upon the irrelevant attributes. It was just these three subjects who encoded their data bases in a way that grouped all the properties together with a given name. The fourth subject, whose "same" judgments were independent of the irrelevant attributes, was the only one who encoded the information about names independently for each attribute. In other words she filed names by attribute values rather than file attribute values under names.

We conducted an extra experimental session with all four subjects to see if retrieval of information about properties on one attribute was independent of retrieval of information about properties on other attributes for a given name. For the first three subjects, as expected, there was a strong and significant correlation between the speed of retrieval of information for a given name on one attribute with the speed of retrieval on another attribute. For our remaining subject, there was no correlation whatsoever. These findings emphasize again that the former subjects have stored information about a given individual in one place while the latter subject has not. Another finding of possible significance, although we

must be cautious because the data are from only one subject, was that this latter subject showed by far the most forgetting when brought back two weeks later. It could be that storing all the properties together for a given name creates a memory structure that is much less susceptible to later memory loss.

Our third experiment was oriented towards those implications having to do with the effects of the initial encoding. Our intention was to see if we could manipulate the encoding strategy that subjects employed in learning our material.

2.4. Hyman, Polf, Wedell, Experiment III.

In this experiment we no longer allowed the subject to master the material in his own way, nor did we embed the material to be learned in the form of a running narrative. The subject was told that he was to learn a list of names and three "facts" about each name. One fact indicated where the individual lived (East or West); a second fact indicated his occupation (Farmer or Grocer); and the third fact indicated how he would vote on the type of bridge construction (Wood or Stone). Some context for these facts was supplied. With three dichotomous attributes, each orthogonal to the other, we had eight different roles or combinations of values. To each role we assigned 4 names. We thus had a total of 32 different names or individuals; with three facts or attribute-values for each name, there was a total of 96 separate propositions that each subject had to learn. The names were realistic, but with the restriction that each was exactly 13 letters in length. Some examples are Clarence Adams, Terry Albright, Arthur Backman and Robert Caywood.

The first part of the experiment consisted of the subject learning, in a paired association format, to provide the appropriate attribute value when presented with a name and the attribute. For example, if he were shown CLARENCE ADAMS LIVES.....on the cathode tube, he would have to supply the value "East" or "West" depending upon which was correct. A given subject always went through these 92 propositions in a given order until he reached our criterion of almost perfect performance. This typically required as many as four or more sessions of one hour each.

To encourage different encoding of the material, the order of the 92 statements varied among our four experimental conditions. In Conditions 1 and 2 we blocked the statements by name. The three propositions about Clarence Adams (lives, works, votes) would appear in sequence, then the three about Terry Albright, etc. In Condition 1, the sequence of attributes was the same for each name. In Condition 2, the sequence varied for each name. We hoped that this form of presentation would force or encourage the form of encoding by name that we observed in the majority of the subjects in the preceding experiment. In Condition 4, we blocked the statements by attribute. All of the statements about where individuals live occurred first, then all of the statements about occupation, and finally all of the statements about voting. We hoped that this format would encourage an encoding in terms of attributes rather than nam . Condition 3 was a control in which the 96 statements were mixed randomly with no ordering either in terms of attribute or name.

Following mastery of this material, subjects were tested over three sessions on just one attribute with pairs of names. When presented with a pair of names, the subject had to respond "same" or "different" in terms

of that attribute. Care was taken to use a different set of pairs each session so that subjects could not learn to associate specific pairs with the value of "same" or "different." The reason for testing on only one attribute was to eliminate the possibility of response competition as an explanation of our effects. To check on the possibility of such response competition, we added a final session in which the subject had to switch to a second dimension for the matching procedure.

We do not have any results summarized at this time. However, our PDP-15 was behaving erratically during the conduct of our experiment. On several occasions the computer broke down in the middle of an experimental session. This resulted in a loss of the data for that session. We had to call the subject back on another day and rerun the entire session from the beginning. We do not know in what ways these interruptions and rerunning of our subjects may have distorted our results. We are analyzing the data anyway, but we plan to rerun the entire experiment as a precautionary check, when we are sure that we have finally tracked down and repaired the problem with our PDP-15.

One thing we quickly learned, however, is that the difficulty of learning the paired associates to the same 96 items varies enormously depending upon the ordering of the items. This suggests that the subjects are learning more than just which attribute value goes with which name-attribute pair. Hopefully, it means that they are embedding the entire set of propositions in different structures. Another finding, if we can believe the elaborate, qualitative protocols we obtained from each subject, is that the particular arrangement of names did not prevent each subject from developing and applying rather rich and idiosyncratic learning strategies

similar to those employed in our previous experiments when subjects were deliberately allowed to study the material in their own way.

2.5. General Discussion and Prognosis.

Our current series of experiments finds us gradually adding more and more controls and simplifications as we try to unconfound sources of variation and as we try to tease out different implications. If we continued our trend, we could eventually find ourselves back in the format and paradigms of the classical verbal learning experiments. The more complex stimulus materials and the more naturalistic approach employed to allow subjects to master the material in ways relevant to how they do it in realistic instructional settings creates a variety of problems for control and interpretation. We believe that our current series of experiments has provided us with some insights on how to bridge the gap between naturalism and tight experimental control.

One way is to follow our current strategy of starting out with quasi-naturalistic and relatively uncontrolled experiments and gradually add controls in a series of experiments. We can have some confidence that our later, tightly controlled laboratory experiment has isolated some essential components of the original situation if we can find similar relationships still holding. A further check on this would be then to reverse the order and go from the findings of the tightly controlled laboratory experiment to predictions about what will happen in the quasi-naturalistic situation.

Our present series of experiments also has convinced us that we have outworn the usefulness of the same-different response format. We need to change to a response format that will give us a richer picture of how the

subject has encoded and used the information in the stored data base. As one example of what has led us to this conclusion, the findings of Experiment II strongly suggest that one form of encoding the material is best for tasks in which the information about the individual is to be used selectively. Another form of encoding might be better when the information about each individual must be retrieved and integrated.

Our main form of testing so far has emphasized the subject's ability to selectively retrieve information about one attribute while ignoring other information about the subject. In trying to accomplish this task, the subject is penalized by a memory organization and retrieval system which activates all the stored information about each name being compared. However, it seems reasonable to expect that this same sort of system would facilitate performance when the task requires the subject to deal with names in terms of a combination of attributes. The same-different matching task can be adapted to get at some of this information, but only awkwardly and with a loss of flexibility.

We plan to alter our testing format to employ verification latencies. The subject will be presented statements involving individuals and attributes and he will have to verify them as being true or false. This format promises much more flexibility in pinning down both the strong and weak features of different semantic organizations of the same content area. Samples of the sorts of items that can be used would be:

1) Clarence Adams lives west.
2) Clarence Adams lives west and works grocer.
3) Clarence Adams and Terry Albright both work as grocers.
4) Clarence Adams and Terry Albright work at the same occupation.
5) Clarence Adams is a grocer and Terry Albright votes for wood.

Item 3) corresponds to the sort of probe we have been employing with our matching format up to now. But for the questions we now need to ask, we need the sorts of information that only the other variations can also supply.

We also, as originally planned, intend to use a variety of other tasks and dependent variables to fully explore the capabilities and limitations of various organizations of a body of (instructional) material for performing a variety of tasks.

3.0. Reicher and Associates

The following description presents a brief progress report of what Reicher has done during this initial period.

One set of experiments is an attempt to find out whether learning a set of codes by rules as opposed to rote learning of the codes has any implications for the long term utilization or memory of the codes. If there are implications we wish to see if there is any sense in which the rules still have some existence in a well learned code. We started by teaching subjects binary to octal codes either with arbitrary pairings or with the rules for the transformation. We then noted initial performance on memory span for binary digits (with the idea being the subjects would encode them to octal for memory purposes and decode them to binary for response purposes) performance after various amounts of practice on the binary to octal transformation, and performance after various intervals after practice. So far it is not clear whether the rules help in any way once the code has been learned even after intervals of six months but we are not very sure of these results and more work is being done to make

them more firm.

A second set of experiments was begun to try to study the problem of segmentation. The problem is usually defined in terms of one of the difficulties people have when trying to understand foreign speech. Many report that the speech seems very fast and one cannot tell where one word ends and another begins. Pictures of waveform make it clear that there are no easy ways to differentiate words in fluent speech. The same problem exists to some extent with children learning reading. Thus, we are trying to find ways of measuring segmentation so that we can study it in detail. We tried a simple visual counting task where subjects tried to count Hebrew letters and English letters presented briefly. Although there are probably some differences they are not impressive enough to convince us that this was a good measure.

A third set of experiments came about because of some unexpected problems when using a probe technique for investigating perceptual recognition. We found that the probe might have interfered in some serious way with the target display. Since I have used this probe method quite alot in the past and since others have followed in studies of word recognition, it would seem important to get the matter cleared up.

4.0. Wickelgren and Associates

Wickelgren's current research is supported, in part, by a grant from the National Institute of Education and, in part, from the present contract. That part that is relevant to the present project involves investigating the common aspects of coding and memory that apply both to the traditional nonsense material and to meaningful material.

The most relevant part of Wickelgren's work during the period of this report was the completion of a study with Ian Begg. This was a study of recognition memory for sentences. The results indicated that the forms of the retention function for entire sentences is the same as the form for other types of verbal memory such as single words, word pairs, etc. The form of the retention function for semantic information was the same as that for lexical-syntactic information, though the rate parameter for lexical-syntactic information was about 50% greater than for semantic information. A completed report will not be ready in time for the present report, but will be included with the next semi-annual technical report.

Other work being done on this project indicates that there is substantial speed-accuracy tradeoff in retrieval from both short-term and long-term memory. These findings can have important methodological implications, especially in interpreting data with low error rates. The findings indicate that at low error rate, small differences in error rate translate into large differences in reaction time.

5.0. Schaeffer and Associates

Schaeffer did not return from his sabbatical in Scotland until September. For all practical purposes, his work on this project does not begin until our next reporting period. He has initiated three research projects. One deals with the hypothesis that rehearsal processes a) produce semantic interference and facilitation effects, and b) they can be triggered by events such as a brief stimulus disruption, unrelated to the decay-dependent processes.

A second deals with aspects of schema formation. One set of studies will evaluate the role of perceptual and action referents in schema formation;

another will investigate the automation of schema components.

A third project is concerned with studying and remedying the reasons for failure to master a certain area of knowledge such as arithmetic skills.

6.0. Keele.

Keele worked on the problem of sequential structure for us during the summer. He also presented a report of this initial study at the Attention and Performance Converence which is included with this report. A brief summary of his work is given here.

A characteristic of most skills, such as reading, typing, driving, football, is a high degree of sequential structure. Events tend to proceed in a highly predictable manner and this degree of prediction greatly facilitates task performance. We are performing some studies to determine the nature of the sequential structure as represented in memory. The event sequences are a series of lights, eight lights in length, and the sequence occurs repetitively. Subjects respond to the lights with key presses so that we are able to measure the reaction time, to each light. We have deliberately chosen sequences of events that are arbitrary in the sense that a systematic grammar does not describe the sequence--i.e., the sequence of events was derived by a random process rather than a systematic process. This randomly derived sequence of eight events then occurs over and over.

There are two simple hypotheses about how these sequences are represented in memory. One hypothesis suggests that events are associated with each other so that as one event occurs the representation of the event that normally succeeds it is evoked. Presumably, this occurs even when

the preceding event is out of its normal place in the sequence. Indeed, that was the manner in which we investigated this hypothesis: Occasionally an event would occur out of place in the sequence. The following event was always one that normally followed the out-of-place event. Despite the fact that position in sequence was disrupted, maintenance of event information led to good performance on the following event. Thus, we concluded that sequences are at least in part represented by event-to-event associations.

A second hypothesis posits that, since different events occur at different sequential positions (e.g., one event is the first, another is the second, etc.), the events become associated with position. To test this hypothesis occasionally a sequence was disrupted by an out of place event. The following event could not be predicted by the out-of-place one. Instead, it was perfectly predictable by position. That is if the fifth event is normally event i, the fifth event is likely to be event i regardless of what the fourth event was. This form of predictability was very difficult to use at fast event rates. Thus, we conclude that sequential structures probably do not involve position information.

The above study was reported at the 5th Attention and Performance conference in Stockholm and will soon be published in the proceedings under the title, "Representations of Motor Programs."

We have just finished another study but have not finished our analyses of the data. Our intent was to investigate the event association hypothesis by another method. Again, we had an 8-event sequence of lights. However, 3 of the 8 lights were identical, each time followed by a different light. If event associations occur then when the frequent light occurs in the

sequence not only should it activate the representation of the light that normally follows, but also it should activate representations of lights that follow the frequent one in other places.

The study of sequential structures will be continued at least through next summer. We are considering looking at "grammatical" sequences derived from the arbitrary sequential structures we have examined. Another possibility is to study how input rhythm interacts with sequential structures.

In addition, we plan on re-instituting some studies of individual differences in processing mode. We have preliminary evidence that some people are basically parallel information processors through fairly abstract levels of memory. Other people tend more to process information sequentially following sensory analysis. Our preliminary work on this problem had a number of faults, however, and we plan to restart soon.

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